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AIRCRAFT FIRE AND RESCUE TRAINING FACILITIES. DESIGN MANUAL 27.--ETC(U)
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Criteria are presented herein for the design of a smoke-abated, aircraft crash and rescue, fire training facility. A newly-developed water spray system provides for the abatement of smoke generated in the hot-fire trainer during the fire training exercise. Contaminated waste water is collected in tankage for appropriate disposal. The design includes a fuel system with nozzle outlets for delivering gasoline or JP-4 to the hot-fire trainer. The use of less volatile fuels will not provide for adequate fuel smoke

(continued on reverse)

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abatement during the ignition phase. Supplementary mock up training aids, required for a complete training facility, are not provided in this document. This information will be available in separate documents.

NAVFAC DM-27.5
FEBRUARY 1980

AIRCRAFT FIRE AND RESCUE TRAINING FACILITIES

DESIGN MANUAL 27.5

APPROVED FOR PUBLIC RELEASE

DEPARTMENT OF THE NAVY
NAVAL FACILITIES ENGINEERING COMMAND
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ABSTRACT

Criteria are presented herein for the design of a smoke-abated, aircraft crash and rescue, fire training facility. A newly-developed water spray system provides for the abatement of smoke generated in the hot-fire trainer during the fire training exercise. Contaminated waste water is collected in tankage for appropriate disposal. The design includes a fuel system with nozzle outlets for delivering gasoline or JP-4 to the hot-fire trainer. The use of less volatile fuels will not provide for adequate fuel smoke abatement during the ignition phase. Supplementary mock up training aids, required for a complete training facility, are not provided in this document. This information will be available in separate documents.

FOREWORD

This design manual is one of a series developed from an evaluation of facilities in the shore establishment, from surveys of the availability of new materials and construction methods, and from selection of the best design practices of the Naval Facilities Engineering Command, other Government agencies, and the private sector. This manual uses, to the maximum extent feasible, national professional society, association, and institute standards in accordance with NAVFACENGCOM policy. Deviations from these criteria should not be made without prior approval of NAVFACENGCOM Headquarters (Code 04).

Design cannot remain static any more than can the naval functions it serves or the technologies it uses. Accordingly, recommendations for improvement are encouraged from within the Navy and from the private sector and should be furnished to NAVFACENGCOM Headquarters, Code 04. As the design manuals are revised, they are being restructured. A chapter or a combination of chapters will be issued as a separate design manual for ready reference to specific criteria.

This publication is certified as an official publication of the Naval Facilities Engineering Command and has been reviewed and approved in accordance with SECNAVINST 5600.16.

D. G. ISELIN
Rear Admiral, CEC, U.S. Navy
Commander
Naval Facilities Engineering Command

TRAINING FACILITY MANUALS

New DM Number	Superseded Chapter in Basic DM	Subject
27.1	1	Large Training Facilities
27.2	2	Training Facilities, Buildings
27.3	3	Training Facilities, Other Than Buildings
27.4	-	Fleet Training Center Firefighting School Facility
27.5	-	Aircraft Fire and Rescue Training Facilities

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AIRCRAFT FIRE AND RESCUE TRAINING FACILITY

TABLE

Section 1. DESIGN CRITERIA

1. SCOPE. Criteria are presented herein for the design of a smoke-abated hot-fire trainer facility for aircraft crash and rescue fire training as depicted on NAVFAC Definitive Drawings 1403956 through 1403963. Design of the smoke pollution control water-spray system is based on data developed by IIT Research Institute which are contained in the NAVTRAEQUIPCEN Technical Report 74-C-0152-1, Development of Smoke Abated Aircraft Crash/Rescue Fire Fighting Trainer, May 1976. The complete training facility will include, in addition to the hot-fire trainer, the following mock-up training aids: (1) Fuselage Trainer, (2) Engine Trainer, (3) Cascade Trainer, and (4) Cold-Foam Pad. Criteria on these additional training aids will be provided by separate documents.

2. RELATED CRITERIA. Certain criteria related to the subject matter appear elsewhere in the design manual series, as follows:

Subject	Source
Mechanical Engineering . . . . Plumbing Systems	NAVFAC DM-3
Electrical Engineering . . . . Electrical Systems	NAVFAC DM-4
Civil Engineering . . . . Water Supply Systems Pollution Control Systems	NAVFAC DM-5
Liquid Fueling and Dispensing Facilities . . . . Fuel Storage and Handling	NAVFAC DM-22

3. POLICY. The criteria contained herein provide guidance for the design of an environmentally acceptable, aircraft crash and rescue, fire training facility which will provide new training techniques to firemen on a local or regional basis. The new training techniques and basic facility requirements were developed in the Naval Surface Weapons Center study NSWC/WOL/TR 75-205, Environmentally Compatible Aircraft Crash and Rescue Training Facilities, 24 October 1975. Navy policy concerning pollution control is stated in OPNAV Instruction 6240.3, Environmental Protection and Enhancement Program, and in DOD 4270.1-M, Construction Criteria Manual.

Section 2. FACILITY ELEMENTS

1. LOCATION. Locate the facility in a remote area of the air station suitable for firefighting training operations where sufficient land is available to construct the training facility and maneuver firefighting vehicles. Provide a clear area surrounding the training area for "no smoking" clearance, pedestrian traffic control, and perimeter clearance. Site selection should consider the availability of electric power and water,

and facilitate construction and operation of a gravity drainage system as described herein to the maximum extent practicable. The facility should be connected to a biological sewage treatment plant for wastewater disposal, but both water supply and wastewater transport can be handled by tank trucks. A fire hydrant should be provided at the site, if feasible.

2. LAND REQUIREMENT. The minimum land requirement is an area approximately 300 feet by 525 feet in plan (3.6 acres).

3. HOT-FIRE TRAINER. These criteria cover a hot-fire trainer which comprises an outdoor fire area containing a centrally located aircraft mock-up. This trainer will enable training in suppression of an actual fire with Aqueous Film Forming Foam (AFFF) using truck turrets and hose lines, and in rescue of personnel from an aircraft under simulated crash conditions.

4. OTHER TRAINING AIDS. The overall facility will include four other types of training aids as follows. Design of these training aids is not included in these criteria.

a. Cold-Foam Pad. A designated impermeable area which will enable demonstration and mastery of crash vehicle operation under "cold" fire conditions, including training in the uniform application of AFFF. The training pad drains to a collection apron and sump from which the AFFF extinguishing agent may be recovered and returned to the crash vehicle for reuse.

b. Cascade Trainer. This device will enable training in extinguishment of open cascading or spraying fires simulating those resulting from ruptured fuel lines. Fires of this type are characterized by no confinement of the various chemical agents used for fire suppression.

c. Fuselage Trainer. A fuselage mock-up or salvaged aircraft fuselage which will provide training with forcible entry tools and interior fire suppression procedures.

d. Engine Trainer. An aircraft engine simulator which will provide training in fire extinguishment which is complicated by hot metal surfaces but assisted by partial confinement.

Section 3. HOT-FIRE TRAINER

1. DESCRIPTION. The hot-fire trainer is a 50-foot diameter, curbed fire pit surrounded by a peripheral drainage system. This circular area contains a centrally-located aircraft mock-up, a bed of crushed rock, a pool of water, piping systems for the distribution of water and fuel, an ignition system, and an internal drainage system, all as described herein. A control chamber containing a weir assembly for maintaining the water pool at constant level is located outside the fire-pit curb. An elevated control building providing good visibility of the fire area is located 150 feet from the center of the burn area. From this building, an operator supplies and ignites fuel and manually controls the rate of spray water discharged

for smoke abatement in the several zones of the trainer during a fire. Storage tanks for water and fuel, together with their respective service pumps and appurtenances, are located near the control building.

2. **FUNCTIONAL REQUIREMENTS.** Trainer design shall incorporate the following special features:

a. Fire Area.

(1) A water sublayer or pool on top of which fuel is floated to achieve uniform fuel distribution.

(2) A fill of crushed rock which protrudes above the liquid surface to reduce fuel movement by wind drag, prevent washout of [illegible]l by the spray water introduced for smoke abatement, and provide an are[illegible] which persons can walk.

(3) A control system to maintain fuel level at [illegible]tical elevation while water is added for smoke abatement and fire exting[illegible]nt during a training exercise. Although the fuel level must be belo[illegible] rock surface, it cannot be deep in the fill because of adverse effects on burning rates, flame heights, and fire severity.

(4) A skimming system for removal of residual foam. Extinguishing agent retained in the fire area inhibits flame spread and rapid development of a subsequent fire. For repetitive exercises with minimum turnaround time, residual foam must be removed after each fire.

(5) Drainage capability to prevent freeze damage in cold regions.

b. Water Spray System.

(1) A smoke abatement system via suitable nozzles spaced throughout the burn area to achieve uniform and effective distribution of spray water.

(2) Division of the fire area into several independently controlled spray-water zones to compensate for the effect of wind on an open fire which results in greater flame height and more smoke generation on the downwind side.

(3) Drainage capability to prevent freeze damage in cold regions.

c. Fuel System

(1) A fuel system which affords completion of fuel delivery as rapidly as practicable and ignition on first fuel entry. For rapid ignition and smokeless combustion, fuels for a smoke-abated crash/rescue trainer must be gasoline or JP-4. If ignition of either of these volatile fuels is delayed until fuel delivery is completed, unburned hydrocarbons are released to the atmosphere and a hazardous flammable atmosphere may be created. On the other hand, if ignition occurs on first fuel entry and much time elapses for completion of delivery and distribution, fuel consumed during this interval is wasted.

(2) Fuel distribution through multiple outlets distributed over the burn area to obtain a rapid and uniform charge of fuel to the trainer.

(3) Drainage capability to prevent damage in the event of water entry in a freezing environment and to permit maintenance work on empty piping.

3. DESIGN CRITERIA. Operation of a hot-fire trainer constructed as indicated on NAVFAC Definitive Drawings 1403956 through 1403963 has demonstrated its effectiveness for smoke abatement. While certain of the design features shown (such as the size of the water storage tank and orientation of the trainer) may be site dependent, system design changes should not be made without due consideration of how they may affect pollution abatement efficiency. Specific design guidance is as follows:

a. Fuel System.

(1) Storage Tank and Pump.

(a) Location. Locate a fuel storage tank below grade near the control tower. See NAVFAC Drawing No. 1403956.

(b) Capacity. Size the storage tank for 3,000 gallons. Fuel will be delivered to the trainer site by tanker truck. The fuel requirement is 300 gallons per training exercise, approximately one-half of which is unburned and can be recovered for reuse. Provide sufficient void space at the top of the tank for draining the fuel piping as required.

(c) Appurtenances. See NAVFAC Drawing No. 1403960. Provide tank nozzles suitable for installation of a service pump, connections for supply and drain lines, and a tank vent line which terminates above the roof of the control building.

(d) Service Pump. Provide a vertical turbine pump with suction at the bottom of the fuel storage tank and directly coupled, electric motor drive mounted on a pad above grade. Pump capacity shall be 600 gallons per minute at a discharge head of 50 feet of water. Provide a recirculation line which includes a pressure-relief valve selected to open at pressures greater than the rated pump discharge pressure and to pass a minimum of 20 percent of the rated pump discharge with the main fuel control valve fully closed. For reliability, consider use of a drive motor rated for continuous duty at shut-off head without overload and inclusion of a casing temperature switch to shut the unit down in the event of excessive operating temperature.

(2) Piping.

(a) Size and Layout. Size the piping system to deliver 300 gallons of fuel in not more than 30 seconds. Use two parallel header and lateral systems located below grade and connected at the far end of the fire area to equalize pressure.

(b) Drainage Capability. Pitch all fuel piping for gravity drainage to the fuel storage tank and provide a drain valve.

(c) Outlets. Locate fuel outlets within the fire area in a square array on 8.5-foot centers as nearly as practicable. Fuel shall be discharged horizontally from a series of side-outlet railing fittings, each of which is a component of the inverted U-shaped assembly depicted on NAVFAC Drawing No. 1403963. Locate the top of each fuel-delivery assembly 1 inch below the water surface as shown.

(3) Controls. Delivery of fuel to the fire area shall be regulated from a control station located in the elevated control building. Design of the control system is shown on NAVFAC Drawing No. 1403960 and shall include the following components:

(a) Main Valve. Provide a shutoff valve in the discharge line from the fuel pump to control the supply of fuel to the trainer. Use a manually-operated, ball-type valve sized to pass 600 gallons per minute at a maximum pressure loss not to exceed 2 pounds per square inch. A 90-degree turn of the valve handle shall fully open or close this valve.

(b) Meter. Provide a fuel meter adjacent to the supply valve. Select a meter to indicate total flow (not rate of flow) in gallons. Flow capacity: 1,000 gallons per minute minimum at a nominal line pressure of 100 pounds per square inch. Furnish a register with zero reset capability and visual or alarm indication of delivery of a preset quantity of fuel.

(4) Appurtenances. If the fuel meter requires protection, provide a suitable strainer in the pump discharge line upstream of the fuel valves and meter. Furnish protection for sudden changes in fuel pressure by means of standard procedures and devices.

(5) Ignition System. Fuel shall be ignited by an electrical spark-ignition system energized manually from the control tower before fuel is charged to the trainer so that rapid flame propagation over the entire fire area results upon arrival of fuel. System components include spark plugs, transformers, a control station, and waterproof conduit connecting them.

(a) Spark Plugs. Provide four igniter assemblies in the fire pit, one in each quadrant close to a fuel outlet. (See NAVFAC Drawing 1409363.) Each assembly shall comprise a heavy-duty, gas-turbine spark plug (Champion FS-47-11, or equal) mounted in the specially designed brass holder detailed on NAVFAC Drawing No. 4005878. Provide support for each igniter assembly so that the top of the spark plug is positioned 1 inch above the water level.

(b) Transformers. Furnish a separate transformer for each spark plug. Standard oil-burner ignition transformers rated 115 volts primary and 8,500-10,000 volts secondary are satisfactory. Short secondary leads are desirable to enhance reliability. Locate ignition transformers in a waterproof junction box as close to the trainer as practicable.

(c) Wiring. Install all ignition system wiring in corrosion-resistant conduit sealed to prevent entry of water or fuel.

(d) Control. Provide a push-button station in the control tower for manual start-stop operation of the ignition system.

b. Water Supply.

(1) Source. Provide clean water for operation of the training facility by connecting to or hauling from the base water distribution system.

(2) Quantity Required. The quantity of water used at a particular facility depends on the frequency and type of training exercises conducted. Most of the need for water is associated with operation of the hot-fire trainer. Water of any significant amount is not involved in use of the cascade or engine trainers. Current estimates of water use per exercise at the fuselage trainer and cold-foam pad are less than 150 gallons and 150 to 600 gallons, respectively. It is expected that wastewater from the hot-fire trainer (after separation of its content of unburned fuel) can be used to meet these requirements. The quantity of fresh water needed is a summation of the following requirements:

(a) Foam Makeup. The foam agent used for fire extinguishment requires about 200 gallons of makeup water per exercise.

(b) Fill Water. Based on a void volume of 50 percent for the rock fill, the approximate quantity of water needed to initially fill the fire pit is 7,000 gallons.

(c) Spray System Operation. Effective smoke abatement is achieved at a uniform spray-water deposit rate of one pound per minute per square foot of fire area at the peak burning rate. The rate of spray-water discharge during a fire is variable, averaging 0.67 pounds per minute per square foot for the duration of a fire. Allowing for overspray and assuming a fire duration of 30 seconds for preburn and 2 minutes for extinguishment, the quantity of spray water required for smoke abatement is 500 gallons per training exercise.

(d) Foam Removal. Extinguishing foam that remains in the fire area, after an exercise, is removed following each fire by adding water via the water-spray nozzles to overflow the fire pit. Assuming further operation of the water spray system for 5 minutes, plus supplemental use of a fire hose during this time to aid the skimming operation, the quantity of water required for foam skimming approaches 4,000 gallons per training exercise.

(3) Storage Tank and Pump.

(a) Location. Locate a water storage tank below grade near the control tower. See NAVFAC Drawing No. 1403956.

(b) Capacity. Size the storage tank for 10,000 gallons.

(c) Appurtenances. When connection to the base water distribution system is feasible, provide a shutoff valve in the supply line upstream of the storage tank and an internal float valve set to maintain the water level in the storage tank at an elevation which affords sufficient void space at the top for draining the spray water piping as required. Provide tank nozzles suitable for installation of a service pump, connections for supply and drain lines, and an above ground tank vent. See NAVFAC Drawing No. 1403960.

(d) Service Pump. Provide a vertical turbine pump with suction at the bottom of the water storage tank and a directly coupled, electric motor drive mounted on a pad above grade. Pump capacity shall be 300 gallons per minute at a discharge head of 350 feet of water. Provide a recirculation line which includes a pressure-relief valve selected to open at pressures greater than the rated pump discharge pressure and to pass a minimum of 20 percent of the rated pump discharge with the main control valve fully closed. For reliability, consider selection of a drive motor rated for continuous duty at shutoff head without overload and inclusion of a casing temperature switch to shut the unit down in the event of excessive operating temperature.

c. Fire Pit.

(1) Curb. To contain the rock fill and water sublayer, provide a low, reinforced-concrete curb around the periphery of the fire pit. The top of this curb should be smooth, level, and 1 inch above the surface of the rock fill.

(2) Floor. Provide a reinforced-concrete base for the fire pit designed to support the rock fill and the water load and incorporate the drainage channels described in paragraph e(1)(a) following. Slope the floor to drain these discharge channels.

(3) Rock Fill. To accommodate installation of water-spray system piping, risers, and nozzles within the fire pit, design for a nominal rock-fill depth of 12 inches. Specify use of relatively large rock of uniform size to minimize the head loss involved in discharging water laterally through the rock fill to drainage channels. Refer to paragraph 5.c for additional guidance on specifying the rock fill.

d. Water Spray System.

(1) Zone Layout. To afford flexible control over distribution of spray water within the fire area for smoke abatement, design the spray-water system so as to provide five separate and independently controlled zones of application: a large central area and four symmetrically located peripheral zones. Locate water supply piping below grade within each zone to provide as closely as possible an overall square array of water nozzles on 8.5-foot centers. See NAVFAC Drawings No. 1403961 and 1403962.

(2) Piping.

(a) Size. Select pipe for a working pressure of 250 pounds per square inch and size it to provide the maximum expected flow at a head loss between the service pump and spray nozzles not to exceed 20 pounds per square inch.

(b) Drainage Capacity. Pitch all water piping for gravity drainage to the water tank and provide a drain valve on each zone system.

(3) Spray Nozzles. Vertical Location. Position the top of all water spray nozzles 3 inches above the operating water level. Provide means of supporting pipes and nozzles plumb and to a common plane to ensure uniform horizontal distribution of spray water over the entire fire area as required for effective smoke abatement.

(4) Controls. The rate of spray-water delivery and its distribution over the fire area shall be regulated from a control station located in the elevated control building. During a fire exercise, an operator will adjust five zone valves and the master valve comprising a control station in response to his visual observation of the fire to limit smoke generation and yet maintain a realistic fire. Provide the following control station components (see NAVFAC Drawing No. 1403960):

(a) Main Valve. A manual shutoff valve in the discharge line from the service pump to control the supply of water to the trainer.

(b) Zone Valves. A valve in the supply line to each zone for individual adjustment of spray-water discharge. Specify manual valves for equal percentage flow characteristics, 150 pounds per square inch maximum inlet pressure, and pressure loss not to exceed 2.5 pounds per square inch at 90 percent of the following water flow rates:

Control Zone	Gallons per Minute
Central (No. 1)	105
Peripheral (Nos. 2,3,4,5)	45 (each)

(c) Pressure Gauges. A pressure gauge downstream of the control valve on each zone supply line to permit reestablishment of valve settings for successive training exercises.

(5) Appurtenances. To reduce the potential for spray nozzle clogging, include a suitable 20-mesh strainer in the water distribution system. Provide protection for sudden changes in water pressure by means of standard procedures and devices.

e. Level Control and Drain Systems.

(1) Level Control. Fuel level in the fire pit shall be closely maintained 0.5 inch below the upper surface of the rock fill by means of an adjustable weir assembly located in a control chamber adjacent to and interconnected with the fire pit. See NAVFAC Drawings Nos. 1403958 and 1403959.

(a) Drain Channels. To limit head loss associated with lengthy lateral flow of water through the rock fill, provide a system of collection channels or trenches in the floor or the fire pit. The collection system shall discharge through the fire-pit curb to the level-control chamber, and shall comprise a main channel on a diameter of the fire area and two equally spaced cross-channels. Water deposited in the trainer area flows a short distance through the rock fill to the nearest trench, and from there to the weir overflow assembly located immediately outside the fire-pit curb. To support the rock fill over the drain trenches, provide channel covers in the form of suitable metal grating.

(b) Weir Assembly. Furnish an adjustable weir assembly for installation in the level-control chamber (see NAVFAC Drawings Nos. 1403958 and 1403959). This assembly provides sufficient weir length in a compact configuration to closely limit the head requirement at the maximum discharge rate; its jackscrew components enable level adjustment as necessary. Water from the trainer enters the weir chamber via the main drainage channel and rises to the tops of the weir troughs. Additional in-flow overflows the weirs and discharges to the surrounding drain tank.

(2) Drain Valve. So that the entire trainer can be dewatered as necessary, provide a valved drain at the bottom of the level-control chamber.

f. <u>Foam Skimming System</u>.

(1) Stop Plate. Extinguishing foam that remains floating in the fire area after a training exercise shall be removed by closing the water exit from the trainer and then adding water via the water-spray system to overflow the curb surrounding the fire pit. To enable closure of the water exit, provide means for insertion of a removable metal stop plate where the main drainage channel discharges through the curb to the level-control chamber. See NAVFAC Drawing No. 1403959.

(2) Drainage Apron and Trench. Provide a concrete apron around the entire fire area, sloped to drain to a peripheral trench adjoining the outside of the fire-pit curb. Design the trench to discharge to the drain tank and cover it with a suitable metal grating. Overspray from the smoke-abatement system; misdirected extinguishing foam and fire-pit overflow comprising foam, unburned fuel, and skimming water are collected in this trench and discharged to the drain. Refer to NAVFAC Drawings Nos. 1403957 and 1403959.

4. CONTROL BUILDING. To enable operator control of the supply of fuel and water to the trainer, provide an elevated, metal control building affording visibility of the fire area.

a. <u>Location</u>. Determine the prevailing wind direction and locate the control structure 150 feet from the center of the fire pit on the upwind side. Orient the structure to enable observation of the fire pit with minimum interference from firefighting trucks and personnel which normally attack the fire from upwind or cross-wind. See NAVFAC Drawing No. 1403956.

b. <u>Height</u>. To provide good visibility, elevate the building 10 feet above the trainer grade on a lightweight steel support structure.

c. <u>Appurtenances</u>. Design the control structure to include the following:

(1) A steel staircase for access.

(2) Insulated wall panels for operator protection.

(3) A large, fixed-pane, tempered-glass observation window.

(4) Additional windows for natural lighting and ventilation.

(5) Interior and exterior artificial lighting.

d. Control Stations. For ready accessibility within the building, locate an electrical control panel for the fuel and water service pumps, and manual control stations for the fuel and water systems.

5. MATERIALS.

a. General. To the maximum practicable extent, use noncombustible materials.

b. Pipes, Valves, and Appurtenances. Use commercial-grade pipe, valves, and appurtenances suitable for use with water or petroleum as applicable. Where indicated, use standard Schedule 40 pipe, wrapped and coated for corrosion protection.

c. Rock Fill. Use gap-graded crushed rock sized to pass a 3-inch screen and be retained on a 2-inch screen. Specify that it be uniform in size, sound, hard, clean and free of dust, and insoluble in water or petroleum fuels. The rock used should not disintegrate under service conditions, either by breaking into smaller pieces or by crumbling into fine material.

Section 4. WASTEWATER MANAGEMENT

1. WASTEWATER SOURCES AND CHARACTERISTICS.

a. Sources. The hot-fire trainer is the principal facility component at which wastewater is produced. While the details of design and operation of the fuselage trainer are unavailable as of this issue, some wastewater will likely be generated at this unit from use of water for fire regulation or extinguishment and scrubber operation.

b. Characteristics. Quantitative information on wastewater characteristics is lacking. Together with the water component of foam applied for fire extinguishment during training exercises at the hot-fire unit, water from operation of the water-spray system for smoke abatement, and water from skimming and draining operations, the composite wastewater will contain unburned hydrocarbons (fuel), AFFF, and a variety of combustion products. From study of similar installations at Philadelphia and Norfolk at which oil fuels were used, it can be expected to exhibit significant dissolved chemical oxygen demand (COD) and biochemical oxygen demand (BOD), most of which appear to result from transfer of fuel and miscellaneous combustion products to the water pool during the heating and cooling cycle which characterizes each training exercise. These studies also indicate that emulsification of the fuel content of the wastewater is avoided at a limited-use facility if the trainer is drained at the end of each day of operation. Starting with a pool of clean water and using No. 2 oil for fuel and AFFF (FC-200) for fire extinguishment, operation of the flight-deck simulator at Philadelphia for three training exercises generated wastewater having an oil content of less than 5 milligrams per liter after gravity separation of free oil, and no emulsification was apparent.

c. Treatability. Exclusively physical-chemical conditioning of the wastewater by any reasonable mode of treatment (including carbon absorption) fails to remove its dissolved organic content to the extent required for direct disposal of treated effluent to a receiving stream. However, the organic content is largely biodegradable and can be removed by biological treatment, provided potential toxicity and foaming problems are overcome by limiting the AFFF content of the wastewater subjected to treatment to 250 milligrams per liter.

2. RECOMMENDED WASTEWATER MANAGEMENT SYSTEMS

a. Background. Because of the likely content of AFFF at concentrations toxic to bacteria, the wastewater should not be disposed of on land via surface application or subsurface absorption. For the same reason, on site biological treatment for direct discharge is also impracticable. In general, disposal of the wastewater is best accomplished in combination with sanitary or other organic industrial wastes in a biological treatment system. This method of disposal entails on-site pretreatment of the wastewater for reduction of suspended solids and free oils, and requires the availability of flows at the treatment works which limit the AFFF content of the combined influent wastes to a maximum of 250 milligrams per liter. Use of evaporation ponds may be feasible in arid regions where evaporation losses are much greater than the amount of rainfall.

b. Resource Recovery.

(1) Foam Agent. Design of the cold-foam pad incorporates a drainage apron and sump from which AFFF solution may be recovered and returned to the training vehicle for reuse, if feasible.

(2) Fuel. Use of recovered fuel at the engine and cascade trainers is feasible.

(3) Water. Reuse of wastewater following separation of its content of unburned fuel is practicable for all functions other than operation of the water-spray system at the hot-fire trainer. The potential includes foam makeup, use of water at the fuselage trainer, filling of the hot-fire pit, and flooding of the hot-fire pit prior to skimming for removal of residual foam and unburned fuel. Intermittent operation of a facility at temperatures below freezing imposes constraints on the opportunity for water recycle. Consideration of reuse should also recognize that while the requirement for fresh water and the volume of wastewater requiring final disposal are minimized by reuse, the strength of the residual waste is increased by repeated internal recycling. Following several cycles within a reuse system, dissolved constituents in the wastewater may well reach concentrations which are detrimental to training or facility operations, and which complicate ultimate disposal of the residual waste.

c. Recommended Systems. General guidance on appropriate waste management systems follows. Inherent in these recommendations is the assumption that the hot-fire trainer is drained at the end of each day of operation to limit the emulsified "oil" content of the wastewater and to eliminate freeze damage during cold-weather operation.

(1) Separation of Unburned Fuel. Since unburned fuel is recovered for reuse, and because such fuel must be removed from the training facility wastewater in any case prior to ultimate disposal, provide a gravity fuel-water separator as the initial component of any wastewater management system.

(2) Recovered-Fuel Storage Tank. Furnish a recovered-fuel storage tank for separator overflow.

(3) Ultimate Disposal by Hauling. In the event that remoteness of the fire training facility precludes connection to a sanitary sewer, discharge separator underflow to storage prior to ultimate disposal by hauling to a biological treatment plant of adequate size. To the extent feasible in a particular situation, wastewater may be cycled from storage for reuse.

(4) Connection to Sewerage. Where connection to a sanitary sewerage system of adequate size is feasible and cost effective, consider provision of holding and equalization capacity after the separator from which wastewater is cycled for reuse and discharged at a low controlled rate to minimize shock loading at the sewage treatment works and facilitate meeting the dilution requirement.

3. SYSTEM DESIGN.

a. Stormwater Runoff. Design the training facility so that all surface runoff from contaminated areas is collected and treated; uncontaminated runoff should be excluded from the collection system.

b. Collection System Layout. Layout of the wastewater collection and handling system will be influenced by facility siting requirements, topography, and subsurface conditions. Design the system so that wastewater will drain by gravity to the fuel-water separator. Pumping of fuel-water mixtures tends to form emulsions and must be avoided.

c. Wastewater Flow.

(1) Peak Flow Rate. Operation of the water-spray system for smoke abatement during use of the hot-fire trainer produces the maximum wastewater flow rate of about 300 gallons per minute.

(2) Volume. The volume of wastewater generated by use of the hot-fire trainer is a function of the number of fire exercises conducted. Following definition of the training schedule, calculate the volume of wastewater to be handled from information furnished in Table 1 on the estimated quantities of wastewater produced at this unit during each training exercise. Make an allowance for uncertainties in emission estimates and entry of stormwater runoff and infiltration into the collection system to the extent that such entry is unavoidable.

d. Fuel-Water Separator. Suitable prefabricated separators are commercially available. Base selection of a unit on the following considerations:

(1) The unit shall be covered. The fuels used are volatile and will vaporize rapidly on exposure to air.

(2) The unit shall be rated conservatively to handle the estimated peak flow rate of 300 gallons per minute.

(3) Fuel skimming shall be automatic.

(4) Transfer of skimmed fuel to the recovered-fuel storage tank shall be by gravity. Pumping is undesirable because of fire hazard.

(5) The unit shall be provided with means to facilitate removal of sludge.

e. Recovered-Fuel Storage Tank and Pump.

(1) Location. Locate a tank below grade adjacent to the fuel-water separator for storage of recovered fuel.

(2) Capacity. Size the storage tank to hold the unburned fuel from a day's operation of the hot-fire trainer at minimum. The quantity of unburned fuel produced at this unit depends on the rapidity of fire extinguishment and is estimated to range from 100 to 150 gallons per training exercise.

(3) Appurtenances. Provide tank nozzles for installation of a transfer pump and connection of supply and vent lines.

(4) Transfer Pump. Furnish a pump for transfer of recovered fuel to the main fuel storage tank and to the cascade and engine trainers.

f. Wastewater Storage

(1) Construction. Open storage is acceptable. If use of an earthen basin is feasible and cost effective, provide an impervious liner or soil layer to prevent leakage.

(2) Capacity. Size basins or tanks for wastewater storage 20 to 100 percent above the estimated maximum requirement based on frequency and rate of withdrawal.

TABLE 1

Principal Sources and Estimated Quantities of Wastewater

(Hot-fire pit, one exercise)

Operation	Quantity (gallons)
1. Fire extinguishment	
Foam application[1]	250
Water-spray system operation[2]	500
TOTAL	750
2. Residual foam and fuel removal (skimming)	
Water-spray system operation[3]	1,500
Auxiliary use of hose[3]	325
Unburned fuel	150
Pit volume above normal operating level	1,850
TOTAL	3,825
3. Fire-pit Drainage[4]	7,000

1 Based on application density of 12 gallons per 100 square feet.

2 Based on a 30-second preburn to achieve a well-developed fire, plus a 2-minute burn time.

3 Based on 5 minutes of spray system operation, plus auxiliary use of a hose during this period.

4 Based on rock-fill void volume of 50 percent.

APPENDIX A
METRIC CONVERSION FACTORS

Conversions are approximate
300 feet = 92 meters
525 feet = 160 meters
3.6 acres = 1.5 hectares
50 feet = 15 meters
150 feet = 46 meters
3,000 gallons = 11,370 liters
300 gallons = 1,137 liters
600 gallons = 2,274 liters
50 feet (water) = 145 kilopascals
8.5 feet = 2.6 meters
600 gpm = 38 liters per second
2 psi = 14 kilopascals
1000 gpm = 63 liters per second
1 inch = 25.4 millimeters
150 gallons = 570 liters
200 gallons = 758 liters
7,000 gallons = 26,530 liters
500 gallons = 1,895 liters
4,000 gallons = 15,160 liters
10,000 gallons = 37,900 liters
300 gpm = 19 liters per second
350 feet (water) = 1,015 kilopascals
12 inches = 0.3 meter
250 psi = 1,725 kilopascals
3 inches = .08 meter
20 psi = 138 kilopascals
150 psi = 1,035 kilopascals
2.5 psi = 17.3 kilopascals
105 gpm = 7 liters per second
45 gpm = 3 liters per second
20 mesh = 840 microns
0.5 inch = 12.7 millimeters
10 feet = 3 meters
2 inches = 50 millimeters
250 gallons = 948 liters
750 gallons = 2,843 liters
1500 gallons = 5,685 liters
325 gallons = 1,232 liters
1,850 gallons = 7,012 liters
3,825 gallons = 14,495 liters
12 gallons = 45 liters
100 square feet = 9 square meters
100 gallons = 379 liters

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